TRIZ Application to Noise Reduction of Home Appliances

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Abstract

In this study, TRIZ was used to solve noise problem related to home appliances. On an air conditioner problem, the physical contradictions arisen due to the insufficient space for the airflow were eliminated with separation rules. As the results, the sound pressure level of the new system was reduced by 2.2 dB(A) compared to that of the old system, and the exhausted air velocity was uniform over the outlet area of the system. For the noise reduction of a refrigerator, using the characteristics of supersystem, the noise was reduced by over 2 dB(A). In these successful results, TRIZ showed its usefulness in solving the problems even with severe constraints.

Key Words : TRIZ, Contradiction, Separation rules, 40 Principles, Air-conditioner, Refrigerator

Introduction

TRIZ is the Russian acronym for "Theory of Inventive Problem Solving". TRIZ suggests us how to develop our creativity and the way to get solutions to almost all of our problems, especially ones found in engineering field. It was G.Altshuller who established the essence of TRIZ[1]. Following him, many researchers have developed TRIZ to make it more powerful and useful[2],[3],[4],[5]. Some researchers produced some software, which helps users of it to apply TRIZ more easily to their own problems[6].

TRIZ is known to be very effective when we have found contradictions from our problem situation. Since TRIZ suggests how to eliminate the contradictions, we can get more innovative solutions than usual ones acquired by conventional ways. There can be defined more contradictions than 3 kinds, as well-known, administrative, technical, and physical contradiction. The contradiction can be acquired by making clear what we want and what prohibits us from getting that. No matter which contradiction we define according to our problem situation, TRIZ can serve the elimination of the contradiction.

Almost all of our problem situations contain several constraints, which preclude the system change of a big investment.

Even though TRIZ suggests novel solutions to every problem, there remain several bottlenecks if we put on them constraints hard to overcome. In this case, we have to find the contradictions between our solutions and constraints. We can eliminate the contradictions by separation principles just as we use them to solve our original problems.

One of the most important methods proposed through TRIZ is "Full scheme", a part of which is called "System approach"[2]. By using "Full scheme", we can get more precise and useful viewpoints about our problems and solutions.

In this paper, we show two cases of solving the noise reduction problems of home appliances attacked with TRIZ, especially, the contradiction formulation and the full scheme mentioned above.

As for home appliances, noise reduction has come to the main factor for leading the market. In general, the control of noise sources is preferable to improvement of noise insulation both in cost and in effectiveness. However, more effective ways of noise reduction require the change of the system structure with new investment not allowed. There is a contradiction between effectiveness and cost for new investment.

We will describe the way to solve this contradiction presenting successful applications to an air conditioner and a refrigerator. In many steps following TRIZ process, we mainly referred to OTSM-TRIZ[2] introduced by Nikolai Khomenko.

Case 1 : Noise Reduction of an Air Conditioner

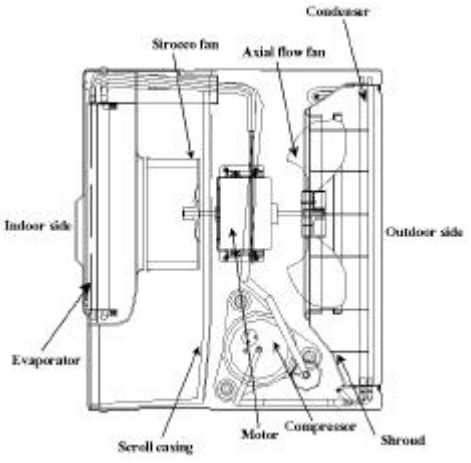

Fig.1 Schematic of a window type room air conditioner

1) Problem Situation

As shown in Fig. 1, a window type room air conditioner is usually composed of a sirocco fan as an inner side fan, an scroll casing to guide the air exited from the fan, a compressor, an evaporator, a condenser and etc. It has two parts of indoor side and outdoor side.

We had to reduce the volumetric size of the system by 40 % compared to the current system in order to use the frame which has been for a smaller model. Especially, the base pan that supports all components of the system must not be changed to keep the cast of the smaller model used. The width of the scroll casing could not be changed due to that reason.

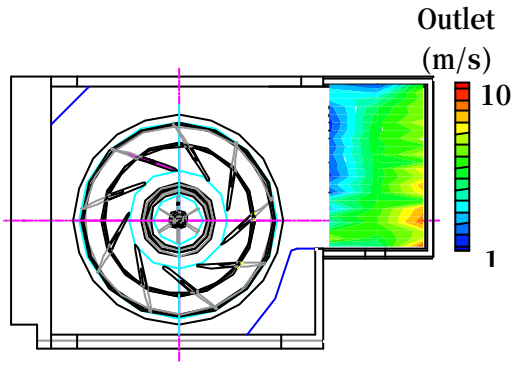

Fig. 2 Discharged air velocity distribution

A turbo fan that would be adopted to make the efficiency higher requires two times larger volumetric space for it than one for the current sirocco fan.

In addition to the size reduction, lower noise level and better sound quality were required. As shown in Fig.2, the out flow of the indoor side did not have uniform velocity distribution that causing unpleasant noise.

No decrease was allowed in performance of the system and no increase was admitted in noise level.

In general, we increase the RPM of a fan to keep the required amount of airflow under a smaller volume of the system. The increase of RPM causes higher air-borne noise.

TRIZ was applied only to the indoor side part.

2) System Analysis

In order to extract contradictions from the initial problem situation, the system analysis was done using "Product Function Analysis" of TechOptimizer[6]. The more complex the system is, the more useful the "Product Function Analysis" is. The reason that we have to make "Product Function Analysis" is for more correct identification of what we want and more exhaustive analysis of resources.

3) Contradictions

Main cause of noise produced by airflow is flow separation, secondary flow, and fluctuation due to narrow area for airflow. Therefore, to reduce the noise generated from the system, larger flow area is required.

From the system analysis, the four components related to the air-borne generation were selected for us to identify contradictions between them and air. One of the contradictions built between them and air is as follows;

For more airflow, the sectional area of the air guide must be increased.

However, for the smaller size of the air conditioner, the sectional area of the air guide must be decreased.

Based on the contradictions, several pairs of improving features and worsening features were selected in order to use Altshuller's contradiction matrix. One of them is as follows;

- Improving feature: volume of moving object
- Worsening feature: object-generated harmful factors

In this case, the four principles are acquired from G.Altshuller's 40 principles.

- 17 Dimensionality Change
- 2 Separation
- 40 Composite Material
- 1 Segmentation

Even if technical contradictions are shown above, many cases can be changed as physical contradictions.

As explained in the problem situation, the scroll casing must have a larger sectional area but that is not allowed since the scroll casing is fixed on the base pan. This physical contradiction was eliminated by the method of "separation in space".

4) Solutions

According to the principles, several conceptual solutions were generated. Not only application of one principle but also combination of more than two principles resulted in effective ways to eliminate the contradictions.

Totally, 4 parts of the system components were changed.

5) Results

Fig. 3 shows the comparison between the noise spectrum of a current system and one of the new system made according to the concepts from TRIZ. Under the same environmental condition and performance requirement, the noise of the new system is decreased by more than 2 dB(A).

The volumetric size of the new system was reduced by redesign of the outdoor side part.

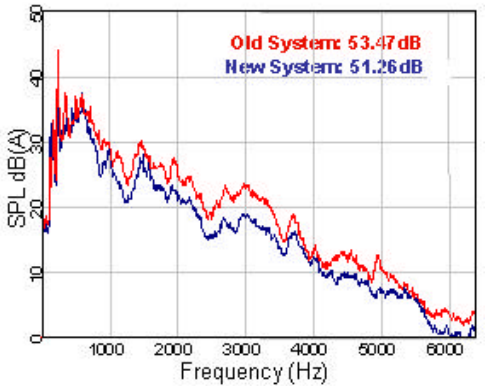

Fig. 3 the comparison between the noise spectrum of a current system and one of the new system

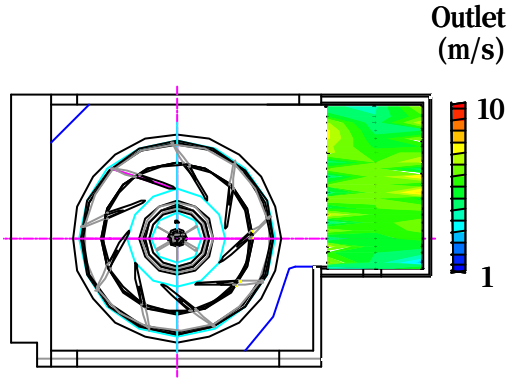

Fig. 4 Discharged air velocity distribution after the modification

As presented in Fig. 4, the new system makes the uniform outflow of the exit on their door side. The uniform outflow results in high quality of sound.

Case 2 : Noise reduction of a refrigerator

1) Problem Situation

The reduction of the air-borne noise of refrigerators has gotten more important in these days. In every time before a new refrigerator is introduced, a more silent cooling airflow system have to be designed in several months. However, the parametric study of a fan system installed in a complex system usually requires experiments of too many times. In the case shown in this paper, only 2 months is allowed for design of a new fan and shroud.

In general, a refrigerator has the air flow system shown in Fig. 5. If just one fan is adopted to circulate the cooling air inside the refrigerator, the fan is set up usually between the freezing compartment and the upper room of the evaporator. The cooling air is distributed along the embedded path.

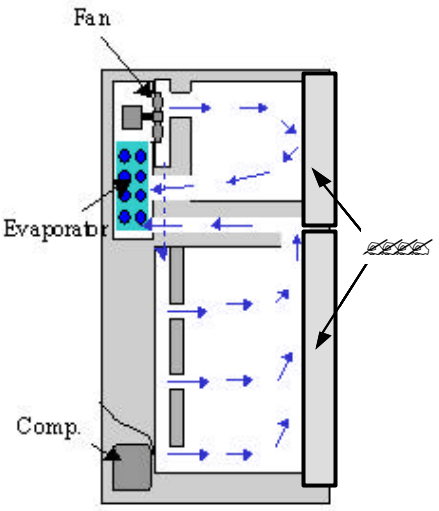

Fig. 5 Airflow inside a refrigerator

2) System Analysis

The "Product Function Analysis" of TechOptimizer was done. From the result of that, several elements were listed as resources.

- Noise source : Fan, Compressor, Air
- Noise Transmitter :
  Damping rubber of the fan motor,
  Damping mount of the compressor,
  Refrigerant pipe,
  Refrigerator body,
  Machine compartment

3) Full scheme

An axial fan for this refrigerator has 3 ~ 5 blades because more blades of an axial fan generally generate larger air-borne noise. Only the improvement of the axial flow fan and the shroud was allowed for this case. However, according to "Full scheme" of OTSM-TRIZ[2], the possibility of using noise transmitters to reduce the air-borne noise was examined.

Based on the previous research[10] which was examined for the possibility mentioned above, one of the supersystem of the fan and the shroud, the refrigerator body was selected as a resource because it was known that the refrigerator door has a role as an insulator in respect to the noise over 700 Hz. In earlier research and development for noise reduction of refrigerators, multi-blade fans like cross flow fans had been tried to design for more silent refrigerator. Even so, more than 5 blades had not been adopted to an axial flow fan for a refrigerator according to the fact that the more blades of an axial fan generates the more noise, "in general".

That seemed due to a psychological inertia. The more blades the axial fan has, the fewer BPF(blade passage frequency) remains significant under the noise insulation property of the

refrigerator doors. BPF is the main factor of fan noise.

4) Contradiction

There is a narrow gap between the tip of an axial flow fan and the shroud. When the axial flow fan rotates, the air passing the gap generates significant noise. The contradictions related to this area are as follows;

- Contradiction 1

The gap must not exist in order to eliminate the noise generated by the air flowing through that.

The gap must exist for the axial flow fan to rotate.

- Contradiction 2

The air between the tip of the axial flow fan and the shroud must not have a high speed in order to eliminate the air-borne noise generated from it

The air between the tip of the axial flow fan and the shroud must have a high speed because the axial flow fan rotates fast.

The contradiction 2 was selected. This contradiction was solved by "Separation in space".

5) Solution and Result

According to the result of "Full Scheme", an axial flow fan with 9 blades was applied. The blades of the axial flow fan were designed for elimination of the contradiction related to the gap between the blade tip and the shroud.

Fig. 6 shows the comparison between the noise spectrum of a current system and one of the new system that has a new fan according to TRIZ recommendation and a new shroud designed by an expert.

Under the same environmental condition and performance requirement, the noise only generated by the axial fan was decreased by more than 2 dB(A). Compared to the old fan system, the new system has less BPF.

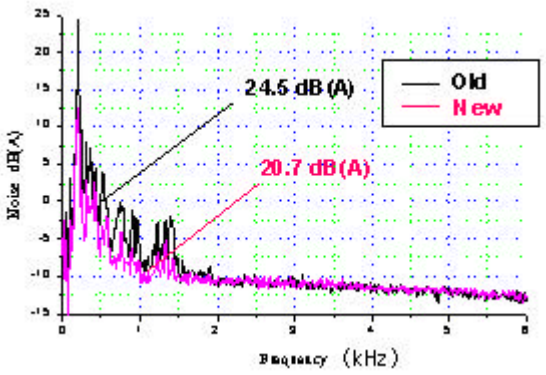

Fig. 6 the comparison between the noise spectrum of a current system and one of the new system

Conclusion

1. TRIZ was applied to the design of a window type air conditioner for noise reduction. Even if under strict limitations, the noise was reduced by 2.2 dB(A).
2. According to TRIZ recommendation, the components of a refrigerator were examined as resources for noise reduction. Using the property of refrigerator doors and elimination of the contradiction between the fan and shroud resulted in noise reduction of more than 2 dB(A).
3. Those successful application of TRIZ to home appliances shows effectiveness of TRIZ even without admittance of radical redesign.

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